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In My Opinion

Rethinking Forest-Bird Habitat Management Guidelines in the Northern Lake States

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ABSTRACT Biodiversity challenges require more ecologically based approaches to habitat management of forest wildlife. Although active management is necessary for the conservation of many forest-dependent wildlife species, some high-severity (even-aged) forest management practices could be improved upon with greater consideration of natural disturbance models. Using examples of 3 migratory bird species of conservation priority and for which high-severity forest management practices are conducted in the northern Lake States (Kirtland's warbler [*Setophaga kirtlandii*], golden-winged warbler [*Vermivora chrysoptera*], American woodcock [*Scolopax minor*]), I first summarize lessons learned and then illustrates how a more ecological approach to forest-bird habitat planning and management might work. Published 2018. This article is a U.S. Government work and is in the public domain in the USA.

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Traditional approaches to wildlife habitat conservation and management were developed when the global human population was a third of what it is today and stressors due to invasive species and climate change were not as pervasive (*sensu* Leopold 1933). Now, in the 21st century, forest biodiversity challenges require a new working model (Pimm et al. 1995, 2006; Lindenmayer and Franklin 2002). The need for more novel approaches to wildlife habitat conservation and management has in fact been the impetus for major policy changes in some wildlife management agencies and other organizations, as well as the development of new professional fields. For instance, many U.S. National Wildlife Refuges established in the 1930s engineered wildlife habitat and altered ecosystems to meet highly specific wildlife population objectives. More recently, refuge policies have refocused management efforts. Refuges are now encouraged to consider broader, more natural landscape patterns, while acknowledging that conservation actions are needed across the matrix of ownership types if biodiversity is to be maintained (Meretsky et al. 2006). For those managing forests, contemporary biodiversity challenges require us to think more broadly about the past, consider what actions or processes produced the forests we now have, and evaluate post-treatment conditions of forest structure, composition, and function (Lindenmayer et al. 2006, Webster et al. 2018).

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The need to evaluate the potential biodiversity effects of forest management has led to the development of forest certification programs and related biodiversity metrics (Guynn et al. 2004, Hagan and Whitman 2006). Forest management approaches within a biodiversity context (i.e., ecological forestry, Gillis 1990) have likewise been developed based on our growing understanding of how landscapes and forests function (Turner et al. 2001, Lindenmayer and Franklin 2002). Originally developed alongside efforts to maintain forest complexity and conserve the northern spotted owl (*Strix occidentalis*) in the Pacific Northwest of the United States (Gillis 1990), many advances in ecological forestry are associated with the growing appreciation and understanding of natural models of disturbances to which silvicultural practices can be compared (Bergeron et al. 1999; Franklin et al. 2002, 2007). Based upon the concepts of many authors (e.g., Seymour and Hunter 1999, Franklin and Johnson 2013) and summarized by Palik and D'Amato (2017:51), ecological forestry has developed the following precepts: 1) context—the importance of planning and management at larger (landscape) spatial scales; 2) continuity—the maintenance of forest structure, function, and biota between pre- and postharvest ecosystems; 3) complexity—the need to create and maintain structural and compositional complexity and biological diversity, including spatial heterogeneity at multiple spatial scales; and 4) timing—the importance of applying silvicultural treatments at ecologically appropriate time intervals.

Active forest management is necessary for the conservation of many forest-dependent wildlife species, including bird species that benefit from high-severity disturbances (Hunter et al. 2001, King and Schlossberg 2014, Kwit et al. 2014).

Habitat for any forest wildlife species is nested within a broader forest ecosystem; therefore, habitat management for a given species affects other landscape and stand-level biodiversity elements. Moreover, because forests develop more slowly than other terrestrial ecosystem types and may have steady states that can last for decades or longer, conservationists are becoming increasingly aware that forest management can have lasting impacts well beyond the goals and objectives that drive a given treatment. Short-term successes based on optimizing objectives may yield long-term limitations. The forest ecology literature is replete with studies that provide the basic premise of this essay: as forest management activities become more focused on outputs, whether timber products or wildlife population objectives, variability and complexity that drive stand-level biodiversity are lost (Lindenmayer and Franklin 2002, Spaulding and Rothstein 2009, Franklin and Johnson 2013, Tucker et al. 2016).

My goal of this paper is to improve forest-bird habitat management guidelines so that they promote future management with a greater foundation in landscape and forest ecology (especially disturbance ecology) and, thereby, provide conditions that maintain biodiversity. My objectives of this essay are:

1. Using the well-documented population recovery of the endangered Kirtland's warbler (*Setophaga kirtlandii*), illustrate how a bottom-up, habitat-specific approach for a Neotropical forest songbird can unintentionally simplify complex forest ecosystems at multiple scales.
2. Improve the development of revised forest-habitat management guidelines for other wildlife species by providing a 5-step framework. While describing the value of each step, I will address how specific habitat management guidelines for 2 migratory bird species of conservation priority in the northern Lake States address the topic and how it relates to the precepts of ecological forestry: context, continuity, complexity, and timing. The 2 focal species and their regional habitat management guidelines are golden-winged warbler (*Vermivora chrysoptera;* e.g., Buehler et al. 2007, Golden-winged Warbler Working Group 2013) and American woodcock (*Scolopax minor;* e.g., Dessecker and McAuley 2001, Dessecker 2008).

Importantly, my aim is not to critique research on the biology of the 2 focal species or claim that forest habitat management conducted under the current guidelines fail to optimize conditions for these bird species. Further, this essay does not subscribe to the dichotomies of timber versus birds, or forestry versus wildlife biology, or public lands versus private lands, but acknowledges that on most forest lands multiple goals and objectives exist, commercial treatments will be required to do most work, and a range of tradeoffs (opportunities and limitations) exist (Butler et al. 2016). My main working assumptions are 1) rather than only optimizing conditions for the target wildlife species, maintaining landscape and stand-scale biodiversity is an overarching goal of those using any forest-wildlife habitat management guidelines; and 2) forest-wildlife habitat management guidelines are written for an educated audience. The northern Lake States is defined as the more northern ecoregions of Minnesota, Wisconsin, and Michigan, USA.

LESSONS LEARNED FROM KIRTLAND'S WARBLER

A stated purpose of the Endangered Species Act (ESA) of 1973 (as amended) is, "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved . . ." (United States Government 1988:1). In the case of the Kirtland's warbler, a Neotropical migratory songbird that breeds in young, dense stands of jack pine (*Pinus banksiana*) historically regenerated by high-severity (crown) fires, successful population recovery actions have involved intensive management of jack pine plantations as surrogate habitat (Donner et al. 2008). Starting in 1957, the Michigan Conservation Commission established 3 management areas for Kirtland's warbler and thereby initiated the first known intensive-management program aimed at recovering a Neotropical songbird (Radtke and Byelich 1963). From these efforts has grown one of the more focused, multiagency, endangered-species recovery programs in the country. Although it is likely that no other bird species in North America is more acutely tied to high-severity forest fires, social and economic factors have made broad-scale application of prescribed fire and managed wildfire untenable. The vast majority of Kirtland's warbler breeding-habitat management in northern Lower Michigan instead consists of clearcutting mature (~50+-yr-old) trees, followed up by planting of 2–3-year-old jack pine seedlings in an "opposing wave" pattern. Birds nest on the ground, under live limbs of densely stocked jack pine. Regularly spaced, unplanted openings in plantations provide foraging sites (Fig. 1). Birds colonize plantations approximately 5 years after they are established and use them for approximately 20 years, at

Figure 1. Aerial image of Kirtland's warbler jack pine plantations in northern Lower Michigan, USA. Diamond-shaped features are unplanted openings in the plantation. Unharvested mature forest is shown in the lower right corner.

which time they look for new, young plantations in which to breed (MDNR 2015).

Without question, intensive, high-severity forest management has been essential for the population recovery of Kirtland's warbler. Over the past decade, the population estimate each year has been above the recovery objective of 1,000 singing males, and estimates over the past 3 years have been >2× this value (MDNR 2015). However, habitat management has had unintended effects on patterns at landscape and stand scales; these altered patterns can have negative consequences for forest continuity and complexity important for biodiversity maintenance. In part, these effects are because breeding habitat management was predicated on the specific needs of the bird (bottom-up) and not on top-down patterns resulting from the disturbance that naturally regenerates forest conditions (fire). Thus, habitat management has met recovery objectives, but has not maintained the ecosystem upon which the bird depends. For instance, at the landscape scale, Tucker et al. (2016) reconstructed the pre-European landscape of fire-regenerated jack pine and compared it with the current landscape dominated by plantations. Results indicated that Kirtland's warbler habitat management has altered the temporal variability of age structure of jack pine stands across the landscape. The current landscape is more homogenized, younger, and more fragmented than the pre-European landscape. At the stand scale, Kashian et al. (2017) had similar results when they compared patterns in jack pine regeneration arising from wildfire versus planting; heterogeneity in the former relative to the later. As suggested by other studies (Corace et al. 2010, 2016), these changes in forest stand age-class distribution and related forest structure may have significant effects on other wildlife species of jack pine ecosystems as well as native flora (Houseman and Anderson 2002).

Plantation management for Kirtland's warbler has also poorly emulated patterns in post-disturbance biological legacies. Biological legacies are forest elements left over from the previous stand after a silvicultural treatment or other disturbance. Biological legacies include retained live trees, standing dead trees (snags), and downed wood, which are essential components to maintain continuity and complexity (Swanson et al. 2011). Although biological legacies are not necessary for the life cycle of the Kirtland's warbler or drive population response, biological legacies serve innumerable ecological functions and contribute to the overall structural complexity and biodiversity within forests (Harmon et al. 1986, Franklin et al. 1987). For example, diverse groups of fungi, plants, and animals utilize snags and downed wood and contribute to wood decomposition and the subsequent release of bound nutrients (Boddy 2001, Jonsson et al. 2005). Kirtland's warbler plantations, however, often differ significantly in the abundance and volume of biological legacies relative to stands treated by fire. For instance, Spaulding and Rothstein (2009) showed that snag density resulting from wildfire produced approximately 100× the density of snags found in young plantations. Kashian et al. (2012) mapped and quantified linear strips of biological legacies resulting from larger (>1,000 ha) wildfires in jack pine and followed their existence over time on the landscape and noted how they are often lost due to salvage logging following fire and before plantations are established. Follow-up studies illustrated the value of these "stringers" for bird species not represented in the adjacent plantations (Cullinane-Anthony et al. 2014).

It is well-established that fire suppression is largely responsible for the conservation status of the Kirtland's warbler. With the population now well above recovery thresholds, forest patterns based on natural models of fire-generated habitat are beginning to work their way into planning documents and management practices (Corace and Goebel 2010; Kashian et al. 2012, 2017; MDNR 2015; Fig. 2). Because effects of fire are poorly emulated by mechanical treatments, however, public agencies associated with Kirtland's warbler habitat management should continue efforts to promote and apply prescribed fire in a safe and effective manner. Such an integrated approach in which natural and surrogate conditions are managed would allow for representation of more biodiversity elements across the landscape. In summary, the Kirtland's warbler example does 2 things: first, it illustrates the power of forest management to meet population objectives; and, second, it illustrates the potential for forest management to have negative consequences for landscapes and stand-scale continuity and complexity when treatments are predicated on species habitat objectives and not natural disturbance patterns.

AN ECOLOGICAL FRAMEWORK

The following is a simplified (5-step), spatially nested, ecological framework to facilitate revisions to forest-bird habitat management guidelines within the context of biodiversity across the northern Lake States and elsewhere. Each of the 5 steps is linked to precept(s) of ecological forestry (e.g., context, continuity, complexity, timing). Although the framework presented may not be entirely new to all forest practitioners, the context of applying the

Figure 2. Structural patterns in fire-generated jack pine breeding habitat for Kirtland's warbler. Although many jack pine plantations established for warbler breeding habitat have reduced levels of biological legacies, these structural features—important for biodiversity—can be managed at virtually no cost during timber harvesting prior to regeneration.

framework to migratory bird conservation in the northern Lake States and many other places is novel. The framework aims to promote forest management that maintains biodiversity and resiliency (DeRose and Long 2014), and takes guidance from the natural models concept (Bergeron et al. 1999, Franklin et al. 2002), the natural range of variation concept (Landres et al. 1999, Drapeau et al. 2016), and ecological forestry principles (Franklin et al. 2007, Palik and D'Amato 2017). The reader should note how this approach differs in many respects with more traditional, bottom-up approaches that have historically been the focus of conservationists (Hunter 2005).

The framework assists with developing goals or objectives by helping to address these overarching questions:

1. What is the natural range of variation in composition and structure associated with different seral stages of forests that develop on a given site under a given disturbance regime?
2. How common are natural patterns across seral stages on a given landscape?
3. Can and should more natural patterns be managed for and which bird species (or other taxa) might such management affect?

The thought process associated with the framework encourages the users to think about the potential range of forest management options and limitations and potential effects of management decisions across larger spatial and temporal scales under the theory that patterns more removed from the natural range of variation have negative consequences for biodiversity (Lindenmayer and Franklin 2002).

STEP ONE

Forest Change at Appropriate Scales (Context)

Golden-winged warbler and American woodcock are 2 migratory bird species of conservation concern with significant breeding populations in the northern Lake States. Regional habitat management guidelines for both species (golden-winged warbler: Buehler et al. 2007, Golden-winged Warbler Working Group 2013; American woodcock: Dessecker and McAuley 2001, Dessecker 2008)

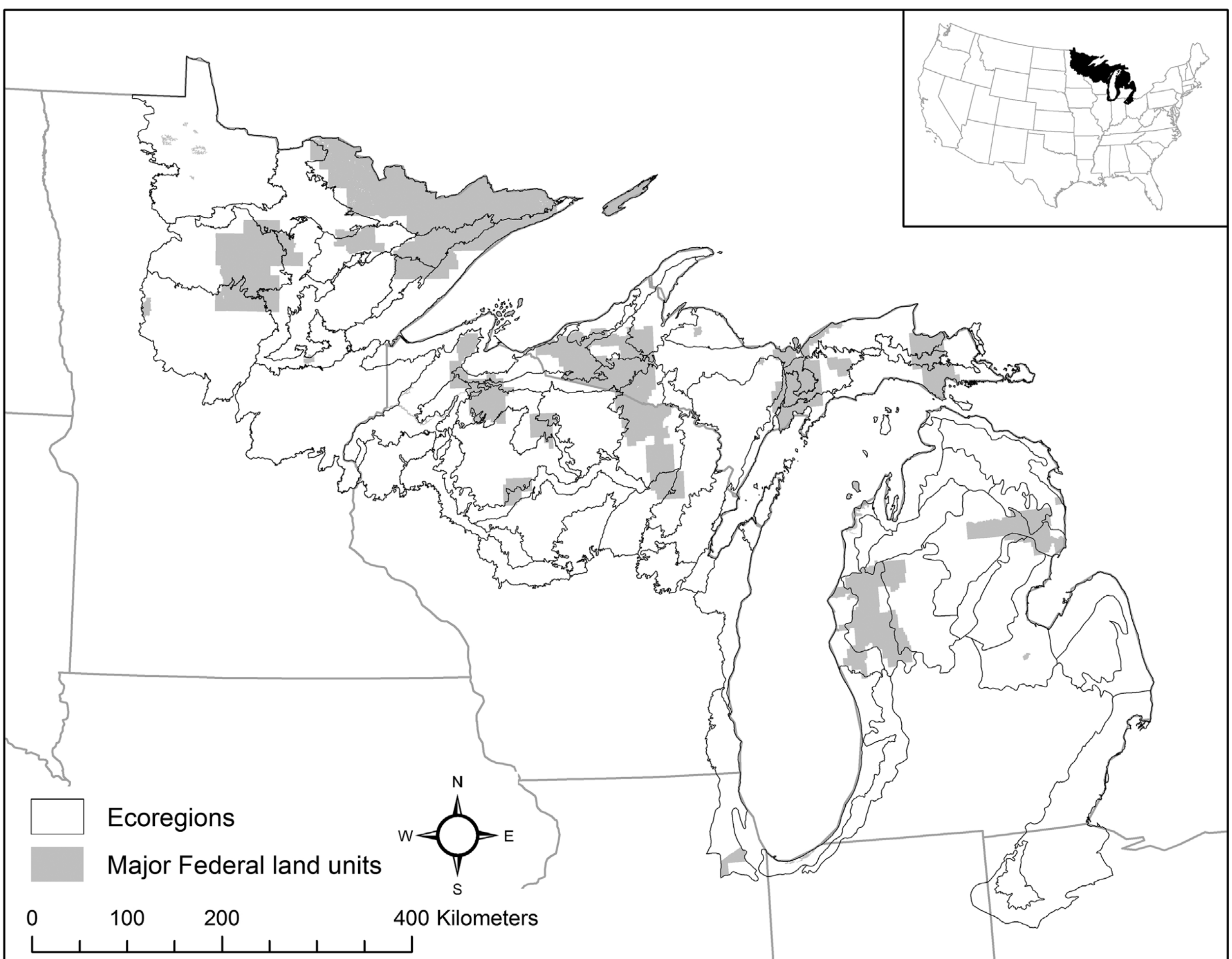

Figure 3. Landscape ecosystems (irregular polygons) of the northern Lake States, USA, as covered by the Lake States Fire Science Consortium and the distribution of major federal land units. Landscape ecosystems are classified based on climate, landform, soils, and vegetation; finer scaled ecosystems are nested in those shown here. Not shown are the other large public ownerships in the region, such as the 1.6 million ha of state-managed forest lands in Michigan, USA. Map provided by Lindsey Shartell.

describe the positive population response of both species to high-severity disturbances (e.g., clearcut, shelterwood, seed tree) in primarily deciduous forests, especially forests dominated by aspen (*Populus* spp.) and aspen–paper birch (*Betula papyrifera*). The golden-winged warbler utilizes post-treatment stands with widely scattered overstory trees, feathered edges, and interspersed patches of shrubs, saplings, and herbaceous openings. The American woodcock uses similar conditions, but with greater stem density of regenerating trees, a more open understory, and more moist soil. The juxtaposition of other, contrasting, cover types is also important for both species.

Habitat management guidelines for both species are often couched into the need to "restore" conditions in the northern Lake States, leaving some to simply ask: what changes have occurred to the regional forests of the northern Lake States? Currently, ownership of the nearly 20 million ha of timberland across Minnesota, Wisconsin, and Michigan consists of nonindustrial private lands, corporate lands, and the largest conglomeration of public lands east of the Mississippi River (Cleland et al. 2001; Fig. 3). Many of the public lands resulted from tax reversion after forests of the region were unsustainably logged in the late 19th and early 20th centuries, a period colloquially referred to as the "Great Cutover." Changes to regional fire regimes and other processes caused changes to forest composition and structure. Relative to regional landscapes farther east, aspen dominance was generally confined to the western periphery of the northern Lake States during pre-European times (Cleland et al. 2001). Landscape reconstructions using General Land Office notes and then comparisons with current U.S. Forest Service Inventory and Analysis Program data now describe a regional landscape with significantly more deciduous tree species, such as quaking (*Populus tremuloides*) and bigtooth aspen (*P. grandidentata*), and fewer fire-dependent conifers (Schulte et al. 2007).

In the northeastern United States, where the post-European settlement period has been longer and both bird species are also to be found, land use change and its relationship to habitat for forest bird species differs somewhat than in the northern Lake States. Studies in the Northeast have discussed forest bird habitat in the context of land use change at time scales relevant to forests (e.g., 100s of yr; Litvaitis et al. 1999). In the northern Lake States, conversely, no mention of the large-scale changes that have occurred over the past 100+ years was found in the habitat management guidelines reviewed for golden-winged warbler or American woodcock, even though it is quite commonly mentioned in the regional forest ecology literature. The baseline used for both habitat and bird populations for American woodcock often dates to the 1960s or 1970s because the American Woodcock Singing Ground Survey was established in 1968 (Dessecker 2008). Such a baseline, within the context of regional forests, represents nearly the peak of aspen dominance due to the Great Cutover, especially when considering the ecology of aspen and its longevity ($\sim\leq 120$ yr) across different landforms and soils. From an ecological perspective, such a restoration baseline may in fact represent the beginning of recovery of many forests in the northern Lake States (Palik and Pregitzer 1992, Webster et al. 2018).

All told, the regional history of aspen and the 2 focal bird species is considerably muddled, especially when "habitat restoration" is used as a reason for forest management. For instance, Brewer et al. (1991:37, 39) suggest that "deforestation" due to the Great Cutover in Michigan caused the population decline in 17 bird species and affected the distribution of another 12 bird species. Every change in the environment leads to winners and losers; therefore, some bird species benefitted from observed shifts in forest structure and composition. The authors suggested 9 bird species in Michigan benefited from the Great Cutover, including the golden-winged warbler. Based on the American Woodcock Singing Ground Survey data analyzed by Dessecker and McAuley (2001), in accordance with Ammann (1991), the American woodcock likely benefitted as well. The point is not that American woodcock and golden-winged warbler do not warrant habitat management actions, but that forest ecology literature should be used along with species-specific literature to objectively provide a land use context relevant to forests and forest management. Like the Kirtland's warbler example, it is possible that birds have responded positively to surrogate (anthropogenic) conditions without natural analogs in the region (e.g., abandoned farmland, high-severity disturbances to forest ecosystems adapted to low-severity disturbances, etc.). Whether or not we should manage for forest conditions without natural analogs (*sensu* novel ecosystem, Hobbs et al. 2006) is an open-ended question worthy of further discussion.

While conservationists think about the future role of aspen forests in the northern Lake States, research suggests ecological, social, and economic opportunities and limitations. For instance, Cleland et al. (2001) reported that aspen has declined 5–21% over the past approximately 40 years across Minnesota, Wisconsin, and Michigan. These aspen declines occurred in some areas even while intensive forest management increased, suggesting other mechanisms may be driving the regional reduction of aspen. Climate models indicate that aspen may not fare well in a warming environment, so the decline in aspen may be more correlated to broader environmental issues (Landscape Change Research Group 2014). Finally, the fickle nature of timber markets that drive many forest treatments is an important consideration in any planning. Ultimately, the future of aspen forests in the northern Lake States is uncertain and complicated; forest managers should be encouraged to think more broadly about the range of conditions that currently exist and are utilized by golden-winged warbler and American woodcock (Gutzwiller et al. 1983, Hanowski 2002, Martin et al. 2007).

STEP TWO

Landscape Ecosystems (Context)

Habitat for any forest bird species is nested within the broader forest and landscape ecosystem. The nested ecosystem classification scheme of Albert (1995) describes spatially explicit landscape ecosystems for the northern Lake

States based on broad patterns of climate, landforms, and vegetation. These landscape ecosystems differ from one another in important ways relative to regional biodiversity (Fig. 4).

Although landscape ecosystems are based on patterns at spatio-temporal scales usually beyond those that typically occur in management actions, these patterns can still influence the efficacy of treatments at the stand scale. Management approaches should therefore differ across the northern Lake States based on landscape-scale landforms and ownership patterns, as well as timber markets, social acceptance, etc. Broad landforms (geology), for instance, can be significant drivers of disturbances and related patterns of aspen regeneration. On shallow soils that historically supported areas dominated by aspen in northern Minnesota, fire regimes and resulting patterns of aspen regeneration differ substantially from fire regimes and resulting aspen regeneration on outwash plains consisting of deep sands farther east (Palik and Pregitzer 1992). However, ecoregional variability is not mentioned in guidelines for the American woodcock. Although landscape ecosystem context is mentioned as part of golden-winged warbler habitat management guidelines, future development of step-down plans for the 16 focal areas in the Great Lakes Conservation Region (Golden-winged Warbler Working Group 2013:4) should be developed with more explicit discussion of the land, its history, and natural models of disturbance.

STEP THREE

Site and Silvics (Context)

Many of the variables associated with a site are finer scaled characteristics covered under landscape ecosystems. Sites can be classified based on finer scaled climate and soil data, for instance, with current forest-site conditions a byproduct of disturbance history (human or other). For instance, tree species generally lumped as aspen are considered weedy because of their prolific asexual nature of reproduction after a disturbance. A given aspen species may grow across a range of sites, but may regenerate best on one site type. Stem density of regenerating aspen is mentioned in habitat management guidelines for golden-winged warbler and American

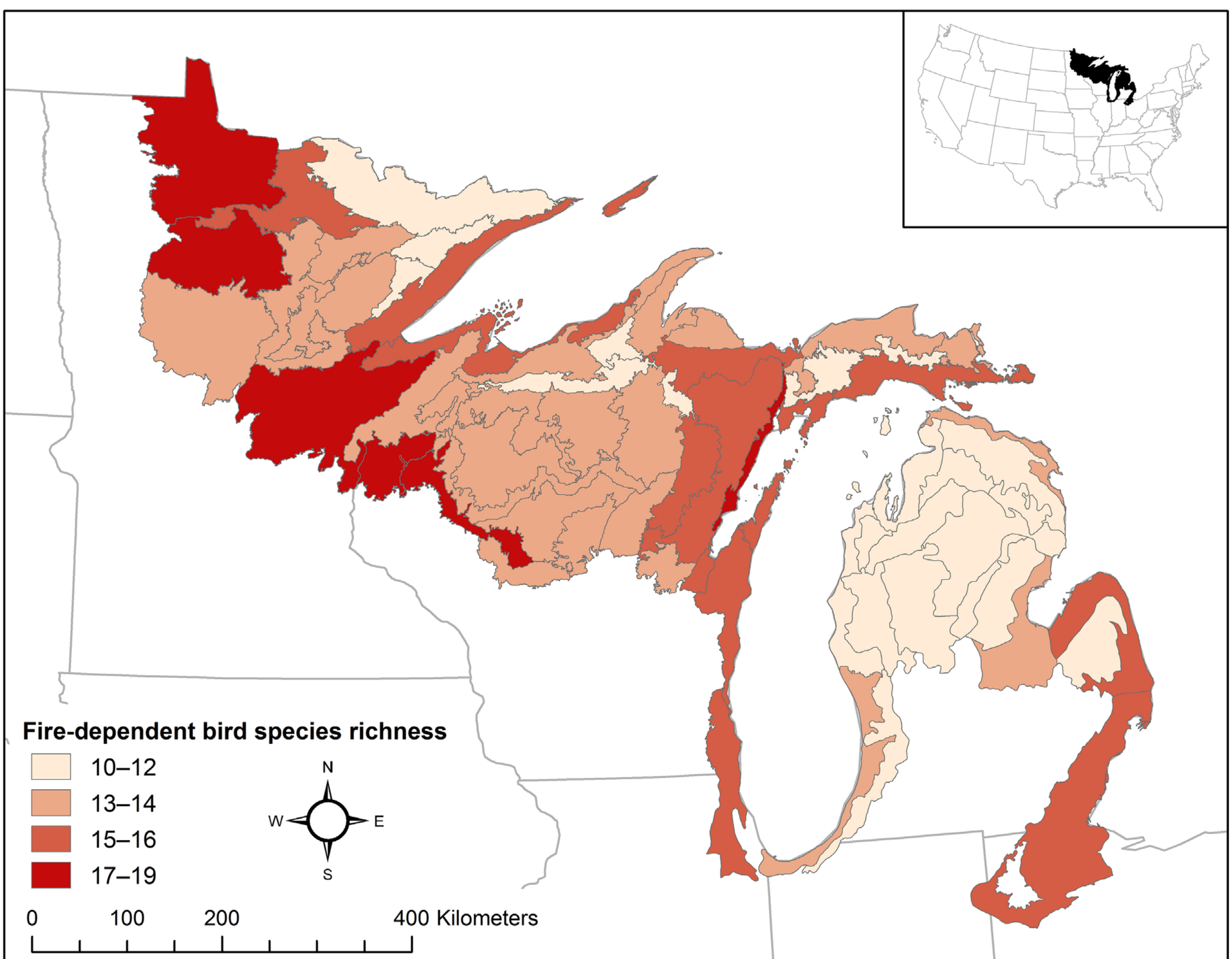

Figure 4. Landscape ecosystems of the northern Lake States, USA, as covered by the Lake States Fire Science Consortium and fire-dependent bird species diversity. Fire-dependent bird species were identified based on their distribution and affinity for native, fire-dependent ecosystem types (mostly forested) as defined by the Lake States Fire Science Consortium (Corace et al. 2015). Map provided by Lindsey Shartell.

woodcock; therefore, future habitat management guidelines should focus more on ecoregional variability in site indices. What one should expect out of a silvicultural treatment in terms of regeneration patterns and corresponding bird response in northern Minnesota should not necessarily be what one should expect from the same treatment in northern Lower Michigan.

In a similar way, soil habitat typing systems can be better used to down-scale ecoregional information to the site, especially when combined with natural disturbance information regarding return interval, seasonality, scale, and severity. Soil habitat typing allows the practitioner to visualize probabilistic pathways of forest development on a given site (Burger and Kotar 2003; Fig. 5). Not only does soil habitat typing assist with planning and management of the overstory, it is also useful for understanding the linkage with specific species of herbaceous ground flora. For each soil habitat type, a ground flora community is used as a predictor of successional pathways of the overstory. For golden-winged warblers, the importance of understory structure (including ground flora) is addressed multiple times in current habitat management guidelines. For American woodcock, open understory and soil moisture are often presented as covariates of occupancy or abundance; soil habitat typing can be used to enhance revised forest-bird habitat management guidelines accordingly. Of note, one of the reasons soil moisture is correlated to American woodcock occupancy is the selection breeding birds have for nonnative annelids (earthworms) as a food source. Interestingly, on many regional National Wildlife Refuges that have managed forests for American woodcock, the presence, abundance, and community composition of earthworms may now be a different conservation concern (Shartell et al. 2015).

STEP FOUR

Disturbance (Context, Continuity, Complexity, Timing)
Different natural disturbances are linked to different landforms and different sites in the northern Lake States (Frelich 2002). The type of disturbance shapes the variability of post-disturbance patterns of structure (Fig. 6). On more mesic sites dominated by deciduous species, natural disturbances are relatively small-scale, individual-tree mortality events that occur relatively frequently and affect trees across a range of size classes. Disease or windthrow are examples of small-scale mortality events. Conversely, on xeric, nutrient-poor sites, conifers, such as pines (*Pinus* spp.), can be found growing in fire-dependent communities. The severity of fire differs, in part, due to the site, weather, past land use, and tree species biology, but effects of fire tend to be greater on smaller diameter individuals or tree species with thinner bark. Although fire disturbances are generally larger in scale and less frequent than individual-tree mortality events, there can be considerable variability. Moreover, fire does not necessarily produce early successional stages of forest. In red pine (*P. resinosa*)-dominated stands of the

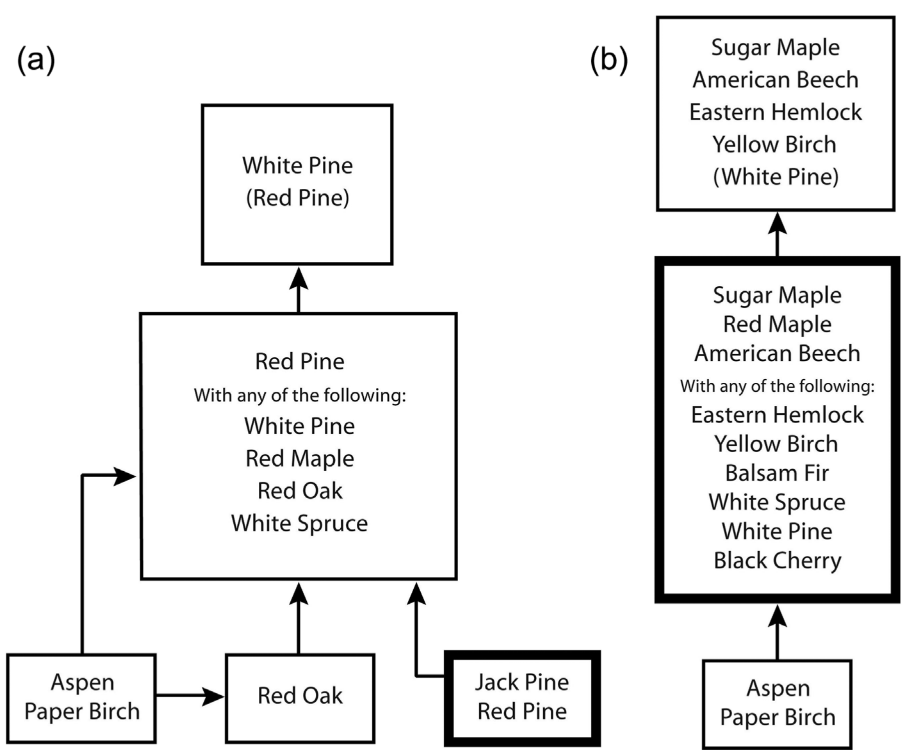

Figure 5. Probabilistic successional trajectories across 2 soil types (a, b) found on the same eastern Upper Michigan, USA, landscape (Burger and Kotar 2003). Each forest type has aspen (aspen–paper birch) as a member of a specific sere, but contrast markedly in terms of successional pathways, disturbance regimes, associated ground flora, and regenerating stem density (see text). Bold lines indicate a forest type that is currently most prevalent across sampling in northern Michigan. Natural disturbance information regarding return interval, rotation, seasonality, scale, and severity is not shown. Images provided by John Kotar.

Figure 6. Postblowdown forest patterns and biological legacies associated with aspen regeneration in Superior National Forest, Boundary Waters Canoe Area, Minnesota, USA. Photo by Doug Shinneman.

northern Lake States, for instance, low-severity fires can maintain the forest type for 100s of years in a mature, closed-canopy condition (Drobyshev et al. 2008).

As severity of a disturbance increases, the probability of new seral stages likewise increases. To maintain biodiversity, forest management should consider the explicit disturbance regimes (e.g., severity, scale, return interval) inherent within landscapes and sites to understanding the natural range of variation in resulting forest structural and compositional patterns. Periodic disturbances to forests are important and vary in origin, type, severity, return interval, and other factors. Some organisms are specific to some disturbances and sites; therefore, contemporary ecological approaches to forest management attempt to link landscape, site, silvics, and disturbance (Franklin et al. 2007). On some sites in the region, clearcuts and other high-severity disturbances have been applied on sites that were historically characterized by low-severity disturbances, illustrating the ecological disconnect among some silvicultural practices on some sites (Fig. 7).

An appropriate period of recovery after a disturbance is also essential if biodiversity elements are to recolonize the site or develop different growth stages post-disturbance. Few natural disturbance regimes of forests in the northern Lake States fall within the combination of return interval and severity as discussed in American woodcock habitat guidelines of Dessecker and McCauley (2001:460, 461), which suggest, "practices must be implemented at regular intervals (approximately every 10 years)" or "20-year rotation across moisture gradients." Golden-winged warbler guidelines for the northern Great Lakes region also seem lacking in explicit disturbance ecology information relating to specific forest types and ecoregions. For instance, both "natural disturbance regimes" and "prescribed fire" are listed under "Management Techniques" (Golden-winged Warbler Working Group 2013:6), but one sentence for each seems inadequate if the nuances of managing complex and variable forest ecosystems are taken into account. Such information could be better addressed in revisions that focus on the 16 focal areas

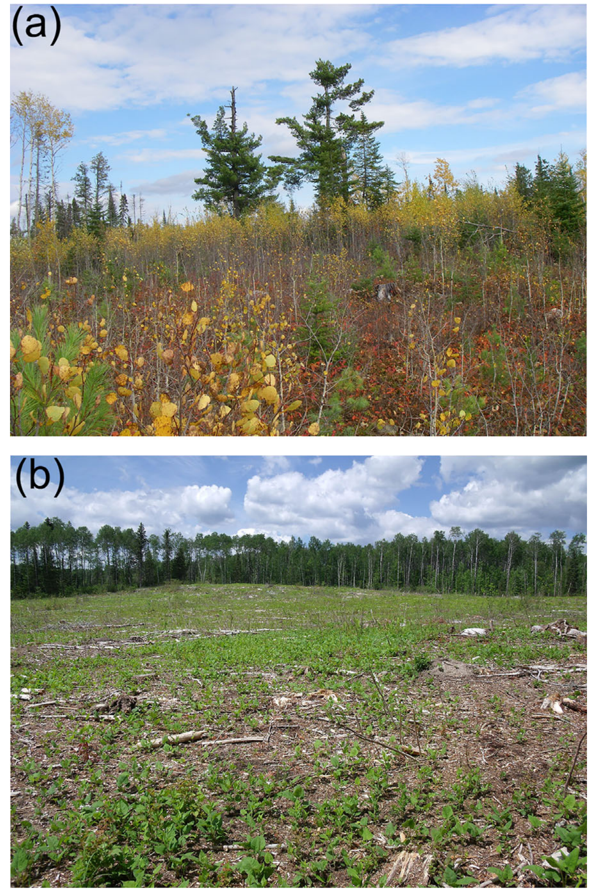

Figure 7. Aspen treatments in northern Minnesota, USA, post-harvest (a) with retention and no site preparation, and (b) with no retention, but with site preparation. Different patterns have implications for biodiversity at the stand level. These patterns can be compared with the natural disturbance example in Figure 6. Photos by Brian Palik.

identified by the Golden-winged Warbler Working Group (2013:4).

STEP FIVE

Biological Legacies (Continuity, Complexity)

As discussed in the Kirtland's warbler example above, biological legacies directly relate to past management activities and their relationship to future forest management options and biodiversity elements. For instance, what individual trees remain on a site after a forest treatment can affect future regeneration because these trees may provide propagules. Moreover, although consideration is often made to the living material in a forest, the dead material is often what drives biodiversity in managed stands. Although the literature on managed biological legacies in the northern Lakes States is not as robust as that elsewhere, the abundance and volume of biological legacies are a byproduct of the type and severity of disturbance and can be quantified for different forest ecosystem types and managed accordingly with wildlife implications (Weiss et al. 2018). If a forest treatment is to attempt to mimic (imperfectly) high-severity fire, for instance, a greater abundance of snags and downed wood and a lower abundance of live material may need to be set as an objective. The inverse is true if the disturbance regime being emulated is low-severity (Swanson et al. 2011). Moreover, the size and species of a biological legacy may be important because these variables may influence longevity and ecological function. Maintaining a diversity of biological legacies in a post-treated stand may increase options for the future, while providing ecosystem function and wildlife habitat in the present.

With respect to early successional forests in general, Swanson et al. (2011:118) wrote, "After severe disturbances, forest sites are characterized by open, non–tree-dominated environments, but have high levels of structure complexity and spatial heterogeneity and retain legacy materials." Later, Swanson et al. (2011:123) state, "To fulfill their full ecological potential, early successional forest ecosystems require their full complement of biological legacies . . . and sufficient time for early successional vegetation to mature." Future habitat management guidelines for the 2 focal bird species should include more detailed discussion on the spatial configuration, abundance, and volume of biological legacies arising from different types of disturbances. Guidelines for golden-winged warbler specifically address the effect of quantified patterns for live biological legacies in that they describe the need for widely spaced residual trees >22 cm in diameter (Roth et al. 2014), but we find no mention of snags or downed wood. Golden-winged warbler guidelines may learn from this and extend their current biological legacy recommendations to a given ecoregional setting, forest ecosystem type, associated disturbance regime(s), and the diversity of biological legacies that result. I found no mention of biological legacies in any habitat management guidelines for American woodcock in the northern Lakes States.

CONCLUSIONS

Besides birds, many other wildlife taxa (e.g., forest-dwelling bats, Chioptera)—found across forest types and seral stages —warrant habitat management in the northern Lake States and elsewhere. Incorporating lessons learned from natural models and communicating this information to conservation partners and the public should be a priority moving forward, especially because managing habitat for bird species that evolved with high-severity disturbances necessitates considerable societal buy-in (Askins 2001).

Forest-bird habitat management guidelines should begin with an explicit, detailed discussion of forest conditions that arise from natural processes across forest types and on specific soil types within specific landscape ecosystems. In other words, forest-bird habitat management guidelines should begin by documenting the following: in what type of forest, on what type of soil, and under what disturbance regime do the recommended habitat patterns naturally result, or do the recommended patterns even emulate naturally occurring conditions? If answers to these questions are not known, practitioners should be made aware and forest research directed accordingly. Although it is understood that in some rare cases drastic habitat management measures are required to avoid extinction, in the majority of instances—and for the majority of forest-bird species and other taxa—this is not so. For golden-winged warbler and American woodcock subregional or landscape-specific revisions to habitat management plans are needed. Using the framework herein described, other pertinent landscape and forest ecology literature, and a team of authors consisting of experts across multiple disciplines, revisions could better address spatial variability in forest ecosystems and related uncertainties in an ever changing world. Climate change, in particular, may affect the scale, severity, and return interval of natural disturbances in the region. These changes (or this uncertainty!) must be quantified and taken into account in future planning and management.

Ecological approaches to forest management are being applied across ownership types because they allow for a range of goals and objectives to be integrated with management that aims to maintain complexity, resiliency, and future management options. The development of ecological approaches to forest management has paralleled similar efforts across other ecosystem types, including wetlands and grasslands (Fuhlendorf and Engle 2001, Euliss et al. 2008). Nonetheless, forest management is an art guided by science, and conservationists must evaluate a range of information beyond species biology and bird priority lists, including contemporary land ownership policies, goals, and objectives as well as broader ecological knowledge, before suggesting if, where, and when forest-bird habitat treatments occur. In this regard, the above framework can be used to down-scale multispecies regional bird-conservation plans to specific landscapes and iteratively guide the establishment of finer scaled goals and objectives regardless of whether a proposed forest treatment is for the management of an individual bird species, a bird community, or broader ecosystem objectives.

Forest-bird habitat management guidelines should focus more on the land itself and its variability over space and time so as to promote management that accounts for context, continuity, complexity, and timing. Greater bird densities, flush counts, nest success, or fledging rates may be no better a focus of management on some lands than more board feet or cords if the results are homogenized forest ecosystems. When the focus is solely on habitat for a focal species and not the forest itself, patterns important for biodiversity, but not specifically driving population objectives, can go unaccounted. More critical discussion of where, how, and why we proceed with forest management for bird conservation is encouraged. Discussions and related outreach that focus on the need for restoring natural disturbance regimes on public lands and the use of natural models to guide forest treatments that produce complex patterns across landscapes, forest stands, forest types, and seral stages are especially needed.

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